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MANAGEMENT HANDBOOK

To Aid Emergency Expansion of

Dehydration Facilities for Vegetables and Fruits

VOLUME II

APPLE SUPPLEMENT

A Phase II Preparedness Study

Prepared at the Request of
Office of the Quartermaster General
Department of the Army
Washington, D. C.

By

Western Regional Research Laboratory
Bureau of Agricultural and Industrial Chemistry
Agricultural Research Administration
U. S. Department of Agriculture

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CHAPTER I

BASIC ASSUMPTIONS

Foreword

The planning of a dehydration plant meeting national emergency needs should take full cognizance of the information and suggestions given in Volume I of this Handbook. This information for an APPLE DEHYDRATION PLANT is based upon the principles set forth in that portion of the Handbook. This presentation differs from most of the other plant plans in that it makes no attempt to give details on plant layout, equipment requirements, operating procedures, and costs.

Product Desired

APPLES, DEHYDRATED, as procured by the Quartermaster Corps, are to be distinguished sharply from the "dried apples" or "evaporated apples" which were a familiar item in the old-time grocery store. While dried apples 1/ are still produced on a fairly large scale, per capita consumption in the United States has declined markedly during several decades, largely as a result of improvements in the storage and marketing of the fresh apple crop and the appearance of new processed (canned and frozen) apple products.

The dried apple of commerce is customarily dried only to a moisture content of 22 to 24 percent, at which point the product is not far from equilibrium with air of average outdoor humidity, and is substantially safe from attack by molds. In storage, however, even at mild temperatures, such as 70° F., adverse changes occur in flavor, color, and texture. At higher temperatures, such as 100° F. or above, the useful life is very short — not more than a few months. For this reason the ordinary dried apple is not acceptable for military use involving either shipment overseas or long-time warehousing, although it has been procured to some extent for prompt use in military establishments in this country.

Shortly before World War II a true dehydrated apple began to be produced commercially. In this product the moisture content had been reduced to only one and one-half to three percent. This dehydrated apple would absorb moisture rapidly from ordinary air, and was therefore packed and marketed in hermetically sealed cans or moisture-vapor resistant containers. Tests of this product showed that it retained its attractive edible quality for a long time in storage, even at 100° F. It was procured on a large scale for the Armed Forces during the war, and is on the current procurement list.

Current Military Specification for dehydrated apples is titled "Apples, Dehydrated" (MIL-A-1035A) dated 23 September 1949 plus an amendment (to one paragraph) issued 2 October 1951. The specification describes two different types of dehydrated apples: Type I (used for sauce) and Type II (used for pies). Only the former was procured during World War II. The pie-stock, which is a more recent development, is more exacting as to the varieties of apples used and the size of the individual pieces of product. Most of the current procurement is for the pie-stock type.

1/ The term "dried apples" as used in this Supplement of the Handbook refers to the usual dried or evaporated apples of commerce with a moisture content of 20% to 22%. "Evaporated apples" are substantially the same product as "dried apples". The two differ mainly in the type of drier used for their production, as explained on page 5.

Limitation of This Report

Dehydrated apples are currently being produced for military use by only one manufacturer. Details of the process and equipment used have never been made public, and are regarded by the owners of this company as valuable business property. Three other companies produced dehydrated apples during World War II, but details of their operations also were considered confidential. This report, therefore, covers only such information as is already public property through prior publication elsewhere. Details of plant layout, equipment, operating procedures, and costs cannot be given. While the broad outlines of plant and process will be described, the prospective dehydrator who is not already familiar with this product must be warned that extensive experimental work and process development may be required before he can be assured of successful operation.

Some of the steps in the vacuum drying process are covered by existing patents. Prospective users of the vacuum process indicated herein should investigate the patent situation before undertaking the construction of a plant.

Sources of Information

The information contained in this report is largely based upon the following publications, to which the reader is referred for additional detail:

Allen, F. W. Apple Growing in California. Berkeley, 1951. (Calif. Agric. Extension Service Circular 178)

Anon. "Dried Apple Firm Adds to Washington Plant Facilities." In: WESTERN CANNER & PACKER 39(8):64, July 1947

Anon. "Naman-Krum Packs Apple Nuggets." In: WESTERN CANNER & PACKER 38(5): 46-47, May 1946

Anon. "Vacu-Dry Goes into Commercial Production on Large Scale." In: WESTERN CANNER & PACKER 37(12):63-65, 99, Nov. 1945

Buchanan, J. H., and Zook, P.A. "What Happens to Fruit in Vacuum Dehydration." In: CHEMICAL & METALLURGICAL ENGINEERING 29:1097, Dec. 17, 1923

Burlingame, B. B. California Apples - Situation and Outlook, 1949. Berkeley, 1949. (Calif. Agric. Experiment Station Circular 395) 30 p.

Falk, K. G., Frankel, E. M., and McKee, R. H. "Low Temperature-Vacuum Food Dehydration." In: JOURNAL OF INDUSTRIAL & ENGINEERING CHEMISTRY, 11:1036-40, Nov. 1919

Havighorst, C. R. "1% Moisture Attained by Vacuum Dehydration." In: FOOD INDUSTRIES 16:258-62, Apr. 1944

McComb, A. H. (assignor of one-half to E. R. Peacock) U. S. Patent 1,929,437, Oct. 10, 1933

Moore, C. C. (assignor to Vacudri Fruit Corp.) U. S. Patent 2,023,536, Dec. 10, 1935

Smock, R. M., and Neubert, A. M. Apples and Apple Products N. Y., Interscience Publishers, 1950 (Economic Crops Vol. 2) 486 p.

Webb, W. A. U. S. Patent 2,283,302, May 19, 1942

CHAPTER II

SUPPLY OF RAW COMMODITY

Characteristics Desired in Raw Commodity to be Dehydrated

The drying conditions necessary for attainment of the very low moisture content (not more than 2.5 percent) required in dehydrated apples are much more exacting than those which readily produce "dried" apples of 22 to 24 percent moisture content. The equipment is expensive, and its size is almost directly proportional to the weight of moisture which must be removed in unit time.

Commercial production of "Apples, Dehydrated" is based upon the use of special dried or evaporated apples as its raw material, so that a large proportion of the evaporation of moisture will be accomplished at low cost. Another reason for this practice is that while the apple drying season is confined to a few months following harvest, the dried apples can be stored with little loss of quality in common storage during the winter and in cold storage during the late spring and summer months, and thus can be used as satisfactory raw material for a year-around dehydration operation.

The quality requirements in the military specification for "Apples, Dehydrated" are, however, very high. In order to meet them, the dried-apple raw material must be especially prepared. It is almost impossible to produce acceptable dehydrated apples from regular commercial grades of dried apples, because of the low tolerance for defects in the dehydrated product. The special requirements will be pointed out in subsequent sections of this report.

Suitable Dehydration Varieties and Commercial Production Data

In Volume I of this Handbook strong emphasis has been placed on the location of dehydration plants in close proximity to an area of heavy production of the raw commodity. The reasons for this emphasis lose some of their force in the case of dehydrated apples. Dried apples can be shipped long distances without elaborate precautions, and their weight is only about 20 percent more than that of the dehydrated product. In this case, availability of the specialized dehydration equipment at a particular location is more important than proximity to an apple producing area. Nevertheless, other things being equal, there would be some real advantages — economic and technologic — in the location of an apple dehydrating plant adjoining an apple drying plant.

Commercial apple drying is done in only a few of the apple-growing areas in the United States, and by far the most of it is done in central Washington and in coastal areas of central California. Less than 10 percent of the national supply is produced elsewhere; New York, Virginia, and Pennsylvania account for most of this. Some of the Eastern apple drying plants dry apples for their own use and do not offer them commercially.

Installed drying capacity has been for some time more than sufficient to supply markets for commercial dried apples. Military procurement of dehydrated apples in the past has required only a small part of the output of dried apples, and a still

smaller fraction of the potential output that could be produced by utilizing the existing drying plants. Thus it seems unlikely that there will be in the near future any incentive to construct new drying plants in other apple growing areas.

Table I summarizes the relative percentages of commercial production of the principal apple varieties in Washington, California, New York, and the United States as a whole. These figures, however, signify little as to the relative amounts of the different varieties which are dried. In recent years about seven to ten percent of the commercial apple crop in Washington and about 25 to 35 percent of the commercial crop in California has been dried. These two states have produced approximately the same quantity of dried product, however, during this period.

Table II shows the quantity of apples used for drying and the tonnage of dried apples produced in the United States during recent years. The over-all ratio between fresh weight and dry weight is now about 8 to 1; 1000 bushels of fruit (approximately 24 tons) yield approximately three tons of dried apples. Table III gives total of commercial production, tons used for drying, and the season-average prices paid for apples in Washington, California, and New York during recent years. Extraordinary variations in these prices are evident. The size of the crop and fresh apple market conditions are the main determining factors. Prices paid for the fresh fruit in California have averaged consistently higher than those paid in Washington; one of the reasons is that the apples dried in California have a somewhat lower over-all shrinkage ratio than the apples dried in Washington, so that the yield of product is higher.

Figure I presents diagrammatically the usual harvesting periods for leading varieties of apples in the principal apple-growing States.

The varietal requirements for Apples, Dehydrated, Type II, differ from those for Type I. According to the specification, Type I may be made from any variety, or blend of varieties, of apple. Type II, on the other hand, may be any variety or blend "containing not less than 75 percent of a hard type of apple which will produce a tender cooked slice that is not mushy". In Washington the hard varieties available in quantity for drying are the Winesap and Jonathan apples; the drying plants also make occasional use of the Newton and Stayman varieties. California's leading variety is the Yellow Newtown, which is classed as a hard variety. Its second most popular variety, the Gravenstein, is the leading source of raw material for drying but becomes mushy when cooked. Not more than 25 percent of the total weight in a Type II blend can consist of soft type apples such as the Gravenstein, the Delicious, or the McIntosh.

The varieties named above as alternatives undoubtedly are not equal in all respects from the standpoint of operators of drying plants and operators of dehydration plants. Specific information which would assist prospective operators to choose between the various varieties is not available, but should be sought, because differences may be expected in the yield, the drying rate, and the susceptibility to heat damage during drying, as well as in the tartness and flavor of the product.

Procurement Problems

As has been previously pointed out, the terms of the military specifications for "Apples, Dehydrated", make it necessary to prepare the dried-apple raw material in a special way. In order to make the differences clear, the usual procedure for drying apples will be described briefly.

Raw commodity for drying is frequently taken from orchard-run stock during the harvest season. The drying season also is extended several months by using certain grades of apples separated out at the time the commodity is withdrawn from storage for fresh-market packing.

Small, poorly colored, and blemished but otherwise sound apples will be separated both from the fresh-market grades 2/ and from the "rots" and other culls, and will be used for processing (including drying). The proportion of the total crop diverted into this group for processing will depend on the size of the crop and on market conditions. The average quality and the proportions of the different varieties used for processing thus will vary with the district and from year to year.

The apples are washed at the drying plant, then peeled and cored by semi-automatic machines. Ordinarily the core-plug which is removed will leave some portions of the carpels (hard seed cases) adhering to the flesh, and if the apple is not accurately positioned in the machine, seeds and portions of the calyx and stem may be left. The peeled apples are inspected and hand-trimmed, then are sliced transversely into rings about 3/16 to 1/4 inch thick.

The apples are treated with sulfur dioxide, generally by spraying the peeled and cored fruit with a sulfite solution and then later exposing the slices to gaseous sulfur dioxide in a "sulfur house". The slices are then dried. (Note: In the past, the term "dried" and "evaporated" had this significance: if the drying is conducted in a natural-draft kiln, the product is usually called "evaporated"; if the product is dried in a forced-draft kiln or in a tunnel dehydrator, it is called "dried". In either method of drying, the moisture is usually reduced to about 20 to 22 percent).

The product is then transferred to large bins, in which the moisture content is equalized and, if necessary, adjusted upward to the desired value by judicious addition of water. After several days of this "tempering", the product is packed and stored. Sometimes a further treatment with sulfur dioxide is given subsequent to "tempering", in order to repress a darkening of the product during subsequent storage.

The defect tolerances in the Military Specifications for both types of dehydrated apple are strict, and make it necessary to use special procedures in preparing the dried apples. In particular, the usual coring procedure used for commercial dried apples leaves too much of the carpels with the flesh. Some apple coring machines are equipped with an auxiliary device which takes an additional spherical cut out of the center of the apple after the usual core plug has been removed. Other machines have been modified to remove an unusually large core plug. Some such operation is necessary for production of satisfactory dried raw stock. In addition, extra care must be taken on the inspection and trimming line to find and trim out other defects such as pieces of skin, calyx, water core, rot, bruises, and the like. Both the reduction in yield and the extra labor add substantially to the cost of the raw material.

The Specification for the Type II pie-stock requires that more than 75 percent by weight of the finished product shall consist of pieces longer than 3/4 inch, and more than 50% by weight shall be pieces longer than one inch. In other words, something approaching typical "pie slices" is desired. Since it is difficult to produce pieces of the desired kind from standard dried apple rings, the original cutting of the peeled and cored apple must be modified. One way which has been suggested (the actual commercial procedure has not been published) is to halve or quarter the apple longitudinally, and then run the pieces (with random orientation) through a slicing machine which cuts parallel slices 1/8 to 3/16 inch thick. While this procedure will produce some small and some irregular-shaped pieces, many of them will have the typical "crescent moon" shape. From the standpoint of the drying operation, the pieces having uniform

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2/ Grading of apples for fresh-market sale varies in different parts of the country. Definitions of U. S. grades may be obtained from the Production and Marketing Administration, U. S. Department of Agriculture, Washington, D. C. Some apple-producing States have established special grade definitions; copies of these Standards may be procured from the respective State Departments of Agriculture.

thickness would be more desirable than those having the variable thickness of a wedge-shaped radial cut.

The specification for Type II pie-stock also requires that not less than 85 percent of the finished product shall be retained on a No. 4 screen (0.187-inch opening), and that not more than two percent shall pass through a No. 8 screen (0.0937-inch opening). Any method of cutting which produces a high proportion of small pieces must, therefore, be avoided.

The producer of dehydrated apples who expects to carry on substantially year-round operation must, of course, make special provisions for storing his dried apple stock. <u>This stock will not improve in storage</u>. Reasonably cool storage and protection from insects and rodents are minimum precautions. The Military Specification requires that the dehydrated product be made from <u>the latest</u> crop of apples. Use of dried apples stored for more than a single season is therefore prohibited.

TABLE I

<u>Relative Production of Principal Apple Varieties in States Drying the Most Apples</u>
(1942 - 1950)

Washington		California		New York		United States	
Delicious	50%	Gravenstein	31%	McIntosh	31%	Delicious	20%
Winesap	31%	Newtown	30%	R. I. Greening	13%	Winesap	11%
Jonathan	7%	Delicious	8%	Baldwin	11%	McIntosh	9%
Rome Beauty	6%	Rome Beauty	5%	Cortland	9%	Jonathan	7%

Computed from data in:

U. S. Bur. of Agric. Economics. <u>Apples — Production by Varieties</u>, 1950. Washington, D. C., 1950.

TABLE II

Apples Used for Drying and Tonnage of Dried Apples Produced in the United States — 1940 to 1949

Year	Apples Used for Drying (Tons)	Dried Apples Produced (Tons)
1940	102,000	12,000
1941	148,000	17,000
1942	177,000	21,000
1943	161,000	17,500
1944	168,000	17,000
1945	112,000	14,500
1946	137,000	18,300
1947	119,000	15,000
1948	61,600	7,700
1949	116,000	14,500

Computed from data in:

U. S. Dept. of Agriculture. Agricultural Statistics, 1950, Washington, D. C., 1950.

TABLE III

Apples Produced in Commercial Areas, Apples Used for Drying, and Prices Paid for Apples to be Dried

State	Apples Produced in Commercial Areas 1946-1949 Average (Tons)	Apples Used for Drying 1946-1949 Average (Tons)	Season Average Price per Ton Paid by Processors for Apples for Drying 1946-1949 Average (Dollars)	1949 (Dollars)	1950 (Dollars)
Washington	743,000	50,100	16	8	19
California	204,000	48,700	22	15	38
New York	372,000	2,900	24	15	13 1/
Other States	1,409,000	7,900	—	—	—
United States	2,728,000	109,600	20	12 1/	22 1/

1/ Estimated

Computed from data in:

Calif. Crop & Livestock Reporting Service. California Fruit and Nut Crops June 1, 1951. Sacramento, 1951 (June 11)

U. S. Bur. of Agric. Economics. Fruits (Noncitrus) Production, Farm Disposition . . 1949-1950. Washington, D. C., 1950

U. S. Dept. of Agriculture. Agricultural Statistics, 1948-1950. Washington, D. C., 1948-50

Wash. State Dept. of Agriculture and U. S. Dept. of Agriculture. Horticulture in the State of Washington, 1948-1951. Olympia (1952)

CHAPTER III

PLANT PROCEDURES AND FACILITIES

Two different procedures are in commercial use to accomplish the final dehydration of dried apple pieces to the specified moisture content of not more than 2.5 percent. One is based upon vacuum drying, the other upon air drying. The preliminary operations, and details of the drying procedure, differ in some respects according to whether Type I product (for sauce) or Type II (for pies) is to be made. Various combinations of these operations are possible.

Operations for Type I Product

This description for making Type I product from dried apple rings by vacuum dehydration is based on previously published material. Figure 2 is a diagrammatic flowsheet for these operations. Figure 3 is a suggested floor-plan for the facilities. 3/

200 — Manufacturing Operations

210 — Raw Material Handling

The dried apples are received at the plant in flat wooden or fiber cases containing approximately 50 pounds net weight. The dried apple rings have been lightly compressed into this container. The material may be removed from the box as a coherent block.

Unpacking

The box or case is opened and the block of dried apples is conveyed to a breaking machine.

Breaking up

The block breaker consists of a cylindrical drum, studded with 2-inch fingers, revolving slowly in a casing. The apple rings are torn from the block and fall through a grid beneath the drum onto an inspection conveyor.

3/ The permission of FOOD ENGINEERING, McGraw-Hill Publishing Co., Inc., to utilize material from an article by Havighorst, C. R., FOOD INDUSTRIES 16: 258-262 (1944) is gratefully acknowledged. (Some of the pieces of equipment shown in this original source have been omitted herein, as they do not apply to the process described in this Handbook.

220-230 — Preparing

Inspecting

Operators inspect the apple rings carried by the conveyor, and reject discolored or otherwise unusable pieces such as those carrying wood splinters. The conveyor discharges the fruit into a cutter.

Cutting

The apple rings are diced, chopped, or extruded through a food-grinder equipped with cut-off knives, so as to give small, uniform pieces approximately 1/4-inch in diameter. Uniformity of size is highly desirable because of the pronounced effect of piece thickness upon the subsequent rate of drying. Any considerable proportion of "chaff" (small fragments) is to be avoided because the Military Specification provides that not more than 2 percent of the final product shall pass through a No. 16 screen (openings 0.187-inch).

240 — Drying

Tray loading

The drying trays are square, 40 x 40 inches in size, very shallow, and fabricated from stainless steel sheet. These trays are conveyed in a continuous line below a chute leading from a small storage hopper which receives the apple pieces from the cutter. A vibrator attached to the chute spreads a thin, uniform layer of the product on the trays. The conveyor speed is set so that 7-3/4 pounds of material is spread on each tray -- 0.70 pounds per square foot, which corresponds approximately to a single layer deep. The trays are set into movable loading racks holding 31 trays apiece — the same height as the vertical vacuum drying chambers.

Such details as the tray size and construction, method of loading, and handling from the loading point to the vacuum drier, as described above, refer specifically only to the plant described by Havighorst (see Footnote No. 3). Available descriptions of operations in the other plants which have produced vacuum-dried apples are not complete enough to warrant outlining alternative methods.

Vacuum drying

It has already been pointed out that most of the necessary removal of water from the fresh apple is accomplished in the preliminary drying process, and that relatively little more moisture needs to be removed to make the specified final product. 4/

4/ Actually, about 95 percent of the evaporation has been accomplished in dried apples which contain 23 percent moisture. Thus if 100 pounds of the original prepared slices contain 15 pounds of dry solids and 85 pounds of water, the same 15 pounds of solids will be accompanied by 4.5 pounds of water in the 23 percent dried apple, and by only 0.4 pounds of water in the 2.5 percent dehydrated apple; of the 84.6 pounds of water to be removed, 80.5 pounds is taken out in the first drying step, only 4.1 pounds in the second, or dehydrating, step.

The further removal of water from dried apples is difficult and expensive as compared with the initial removal of water from the fresh apples.

One of the ways of accomplishing the final drying with minimum damage to the product (such as "browning" and changes in flavor) is to conduct the drying under reduced atmospheric pressure -- that is, in a partial vacuum. The reason this is true is briefly explained below.

The rate at which any material will dry is basically determined by just two factors: (1) the pressure of the water vapor in the space surrounding the material, and (2) the physical nature, temperature, and thickness of the pieces of material.

The nature of the material (including the moisture content) and its temperature determine the vapor pressure of the water within the material; this vapor pressure represents an escaping tendency of the water. The vapor pressure increases as the temperature of the piece increases. It is always less than the vapor pressure of pure water at the same temperature, and the vapor pressure decreases rapidly as the moisture content of the piece is reduced — approaching zero in a completely dry material. The rate at which water will evaporate from the surfaces of the piece is proportional to the difference between (a) this vapor pressure of the internal moisture and (b) the pressure of the water vapor in the surrounding space. If the latter (b) can be diminished (as it is if a high enough vacuum is maintained in the surrounding space), the difference between the pressures (a) and (b) will increase and the drying will be accelerated.

It must not be forgotten that heat must always be supplied to evaporate water, whether the evaporation takes place in a vacuum or otherwise. In the substantial absence of air which might serve as a carrier of heat, vacuum driers must be arranged to transfer the required quantity of heat to the wet material either by radiation, or by conduction through the supporting surfaces, or both. The supporting surfaces may be hollow metal shelves through which steam or hot water is circulated, or they may consist of a pancake or grid of pipes which carry the heating fluid. In the plant described by Havighorst, hot water under pressure was used, with control equipment allowing the water temperature to be varied in accordance with a predetermined schedule up to a temperature as high as 333° F. If the drying characteristics of the material were already well established through pilot tests, the temperature schedule was maintained by a specially cut time-cycle cam on the temperature controller. Manual temperature control was also possible, the operator being guided by the indications of thermocouples buried in the wet material at several locations within the vacuum chamber. According to Havighorst, the temperature of the material remained in the range of 100° to 135° F. during most of the drying time. Presumably it would be allowed to rise somewhat higher as complete dryness was approached, but great care would have to be taken to avoid the "browning" which is characteristic of heat damage. The temperature schedules which have been successfully used in practice have not been published.

The drying time (and hence the daily output of the drying equipment) will be strongly affected by the thickness of the pieces

and their internal structure. Drying will be relatively fast if the pieces are very thin or if they can be puffed (like popcorn) so that moisture has to traverse only very thin sections of solid flesh before it encounters a vapor space. Puffing can, in fact, be accomplished quite simply by first closing off the vacuum line at some intermediate stage of the drying, then introducing direct steam into the chamber to raise the pressure somewhat and also raise the temperature of the product, and finally rapidly re-establishing full vacuum. Under these conditions the remaining moisture in the product will "boil" momentarily and produce the puffing effect. If the full vacuum is then maintained until the drying has been completed and the product has been cooled back to room temperature (by circulation of cold water through the supporting shelves), the final product will retain this puffed condition. It will then, however, be too bulky to permit packing of the specified weight in a can. A denser product can be obtained by releasing the vacuum while the material is still hot and somewhat pliable; the sudden increase in pressure than collapses some of the distended cells and the piece shrinks.

According to the Military Specification the dry product must not contain more than 200 parts per million of sulfur dioxide. The dried apple raw material customarily will be sulfited to a much higher level than this. Sulfur dioxide will be liberated to some extent during the vacuum dehydration (leading to some corrosion difficulties in vacuum pumps, steam jet ejectors, and valves), and careful experimentation will be necessary to determine how high an initial sulfur dioxide concentration can be tolerated and what steps can be taken during the drying to increase sulfur dioxide removal if that is seen to be necessary. A succession of treatments with direct steam and reestablishment of vacuum (like the puffing process) is mentioned in the Havighorst article as a commercial method of removing sulfur dioxide.

A technique which has been suggested for judging the end-point of the drying operation (that is, reduction of the moisture content of the pieces to not more than 2.5 percent) comprises making a running record of the difference in temperature between the pieces themselves (as measured by buried thermocouples) and the circulating heating fluid. This difference will be large at the beginning of the dehydration, but as the rate of drying slows down the product temperature will approach closer and closer to the temperature of the heating medium. An empirical relationship probably can be found between this temperature difference and the moisture content, with minor corrections for differences in the product temperature and system pressure in individual cases.

Tray unloading

Apple pieces dehydrated to 2.5 percent moisture will absorb water very rapidly from air of average relative humidity, hence the trays of dry material unloaded from the vacuum chamber must be transferred without delay to an air-conditioned packing room. If the atmosphere in this room is maintained below about 20 percent relative humidity, uptake of moisture by the product will be slower, but the detraying and packing operations must still be carried out promptly.

Tray unloading may be accomplished by inverting the trays over a hopper and, if necessary, scraping lightly.

250 — Inspecting

Dry product from the unloading hopper is spread lightly on a conveyor inspection belt. Operators pick out by hand any pieces which show discoloration or other defects.

260 — Packaging and Packing

Filling, packing, and sealing

Inspected product is conveyed to a filling hopper, which discharges it into the No. 10 cans (which are specified for this product). If the dry material tends to run high in proportion of "fines", a vibrating screen between the inspection belt and the filling hopper is used to separate out the "fines". An operator will adjust, with check weighing scales, the net weight to the specified minimum of two pounds and four ounces. The cans may be vibrated at this point to pack the product, if necessary to obtain the minimum weight. A copy of the specified directions for cooking is inserted in each can. Lids are then seamed on the cans in a standard closing machine. (Note: dehydrated apples are not required to be packed in an inert gas such as nitrogen or carbon dioxide.)

Case-forming, filling, sealing, and marking

At this point the filled cans may be conveyed out of the air-conditioned space. Lacquering (or pro-coating) and casing are carried out by the standard procedures. Details of case construction and marking are given in the Military Specification.

270 — Warehousing and Shipping

The cased goods are conveyed either to the shipping conveyance or to the finished-product warehouse. All practical means should be taken to keep the temperature of this warehouse low, in order to slow down the inevitable deterioration of the finished product. If the material is warm when packed, it is advisable not to stack cases tightly, so that they may have a chance to cool to warehouse temperature within a few hours.

Operations for Type II Product

In lieu of the vacuum dehydration process described under "Operations for Type I Product", apples also can be dried to a moisture content below 2.5 percent by exposure to a warm, very dry air stream.

Figure 2 gives a suggested flow-sheet representing a possible process for making Type II product by air drying (conveyor type drier) in a dehydration plant located adjacent to an apple drying plant in which the raw peeled and cored apples have been pre-cut to the desired piece shape.

While it is known that the Type II dehydrated apples are being produced successfully by an air drying process, no description of the operation and equipment has been published. It is,therefore, not possible to give here more than the barest sketch of operations which are probably necessary.

200 — Manufacturing Operations

210 — Raw Material Handling

Dried apples, prepared to meet the requirements of the dehydration plant (See "Supply of Raw Commodity" — Chapter II), may be warehoused in tight boxes, barrels, drums, or other suitable containers, or, under proper conditions, possibly warehoused in bulk. When dried apple stock is transferred to the plant, net weights are recorded and the containers unloaded onto a conveyor feeding the processing line.

220-230 — Preparing

Inspecting

Operators examine the material passing before them on an inspection belt, and reject discolored pieces and pieces carrying obvious portions of peel, calyx, carpels, and other defects.

240 — Air Drying

When the raw material contains only 22 to 24 percent moisture, as it does in this case, the remaining amount of moisture to be evaporated is quite small, as was pointed out previously. In this range of moisture content, the drying rate of the material will be substantially unaffected by the velocity of the drying air past the material, and the material will attain a temperature only slightly lower than the dry-bulb temperature of the air. 5/ Air flowing through a rather thick layer of the dried apple pieces will not be very greatly cooled by giving up heat for evaporation, as relatively little evaporation actually occurs. At moisture levels approaching the desired end-point (2.5 percent), the rate of further drying will be strongly affected by changes in the temperature of the material and the relative humidity of the air. Drying rate will also be inversely proportional to the square of the thickness of solid substance through which the moisture at the center of the piece has to diffuse to reach the surface — for example, halving the solid thickness will quadruple the rate of drying.

It is apparent from the foregoing that a continuous conveyor type of drier, in which a perforated belt is loaded with a deep layer of dried apple pieces, should be suitable. Such a type of drier is assumed in the following discussion.

"Puffing" of the product, such as can be accomplished in a vacuum drier, does not occur in an air drier. A somewhat similar result, however, which might be called "honeycombing", may be obtained by proper choice of drying conditions. The dried apple pieces, being still quite soft and flexible, can undergo some further volume shrinkage as the remaining moisture is removed. If the initial drying conditions favor rapid drying (relatively high temperature and low humidity) the surfaces of the pieces will quickly become quite dry and hard; they will be "set" in substantially the dimensions of the original pieces. As subsequent internal drying takes place, internal shrinkage tensions will be set up which will split the fruit tissue near the

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5/ See the more comprehensive discussion in the processed bulletin AIC-300, "Principles of the Drying Process, with Special Reference to Vegetable Dehydration", W. B. Van Arsdel. BUR. AGR. AND IND. CHEM., U. S. Dept. Agr., 1950

center, and the flesh will then shrink <u>outwardly</u> toward the hard surface layer, opening up one or more internal voids. Such an occurrence may have a profound accelerating effect on the rate of subsequent drying, because the effective thickness of solid tissue is then much smaller than in the original pieces.

No published information is available on the optimum depth of belt loading, air temperatures and humidities at the various stages, or total drying time in a conveyor drier used for producing Type II dehydrated apples. Many combinations of these operating variables are possible, and comprehensive drying experiments must be made by a new operator before he will be able to make acceptable product with assurance. <u>These experiments must include measurement of the decrease in sulfur dioxide content during the final drying</u>.

It seems likely, on general principles, that the last stage of this dehydration, which must carry the product to or below 2.5 percent moisture, may be feasible with unconditioned warm air during a cold winter season, but not when the weather becomes warm and humid. If the operation must be run in the spring and summer seasons, the air supply to the drier may have to be dehumidified (see U. S. D. A. Bulletin AIC-300, pages 38-41).

<u>250</u> — <u>Inspecting</u>

The dry product discharged from the conveyor drier is spread on an inspection belt, where operators reject discolored or otherwise unacceptable pieces.

<u>260</u> — <u>Packaging and Packing</u>

An amendment to Military Specification MIL-A-1035A, dated 2 October 1951, provides that an average of two pounds net weight of the Type II product shall be packed in a No. 10 can and that no individual can shall contain less than 30 ounces or more than 34 ounces. The amendment says that this requirement can be met by warming the product to not over 130° F. and compressing it into the can with a pressure of approximately 20 pounds per square inch. On the area of a No. 10 can this corresponds to a total force of about 600 pounds. It may be presumed that a withdrawable metal sleeve somewhat longer than the height of the can is inserted in the empty can, warmed product filled into the sleeve to the required depth to give two pounds net weight, and a press plunger then compresses the material in the sleeve and holds it down while the sleeve is withdrawn. Unless this operation is conducted rather deliberately, or a "holding time" under pressure is allowed, the compressed product will tend to spring back gradually for several minutes and make it impossible to close the can.

The other packing operations are as for the Type I product.

<u>270</u> — <u>Warehousing and Shipping</u>

These operations and requirements are similar to those for the Type I product.

Material Balances

The yield of product obtainable from unit weight of dried-apple raw material depends, of course, not only on the weight of moisture lost in the final drying but also on such process losses as rejections of the raw material inspection line, rejections on the finished product inspection line, and "fines" screened out of the final product.

Yields calculated from moisture loss alone are summarized in Table IV.

TABLE IV

Yield of Dehydrated Product (Containing 2.5 Percent Moisture) Obtainable from 1,000 Pounds of "Dried" Apple Stock (Moisture-Loss Alone Being Considered)

Moisture Content of "Dried" Apple Stock (Percent)	Maximum Yield of Dehydrated Product (2.5 Moisture) from 1,000 Lbs. of Raw Material (Pounds)
20	821
21	810
22	800
23	790
24	780
25	769

Since no information is available on the actual magnitude of the other processing losses experienced in operation, no estimates of true yields or material balances can be presented.

Necessary Process and Quality Controls

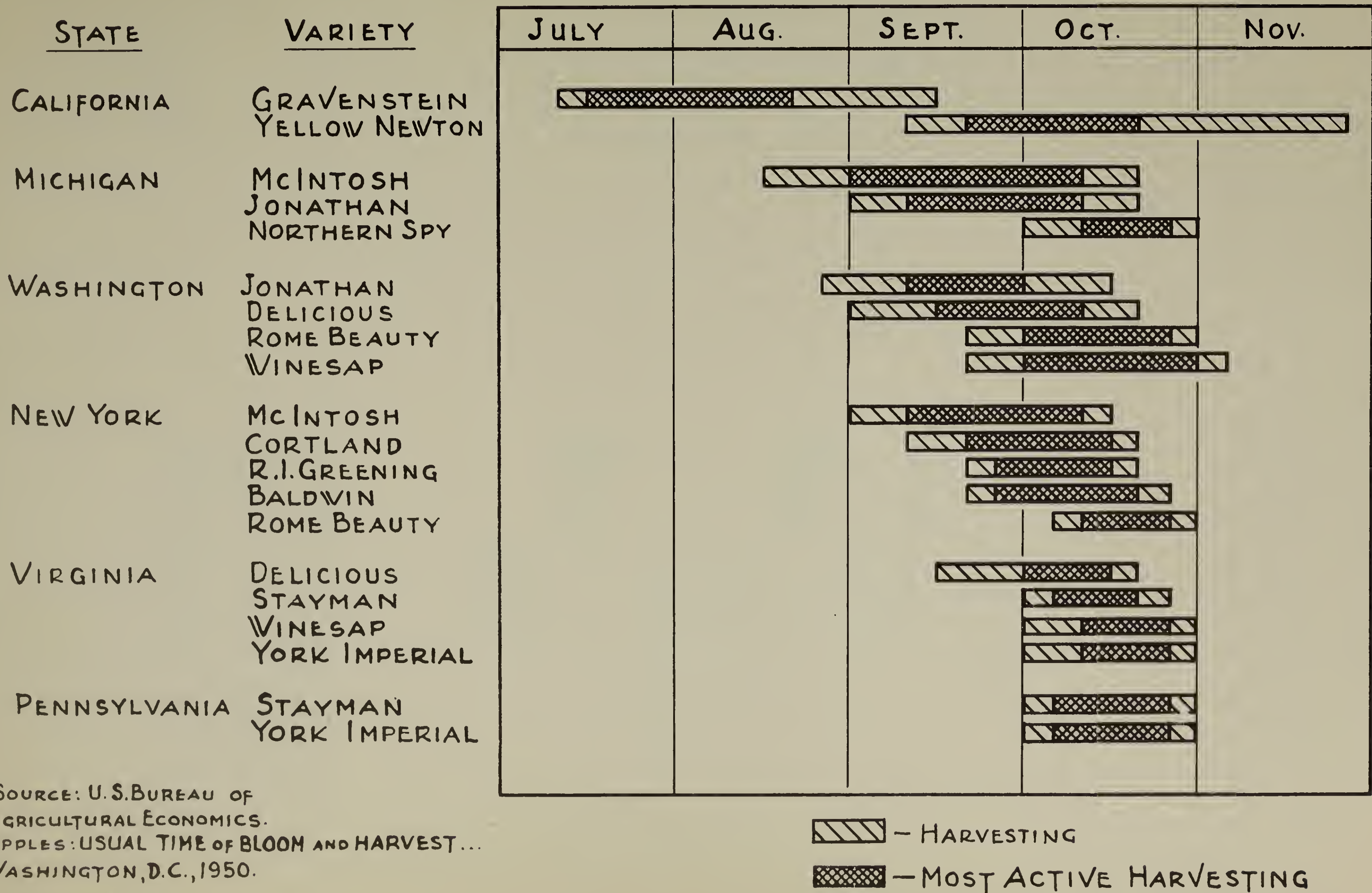
Insofar as they can be inferred from available information, necessary process controls have been mentioned in the foregoing descriptions of the processing operations.

Routine quality controls will be necessary not only to assure the dehydrator that the material he is packing will be acceptable under the purchase specifications, but also to enable him to follow variations in the incoming raw materials so that opertions can be adjusted accordingly. The Military Specification establishes limits on apple variety used (for Type II), screen size and (for Type II) the measured length of the dry pieces, sulfur dioxide content, moisture content, discoloration due to heat damage (none is allowable), and various named defects. A rehydration test is specified.

Building and Equipment Requirements and Costs, Production Costs, and Total Capital Requirements

As will be evident from the foregoing discussion, the amount of information available on the production of dehydrated apples is too scanty and fragmentary to warrant any detailed list of the necessary equipment or any estimate of production costs and capital requirements. Any person not already familiar with the industry is urged in the strongest terms to make a thorough experimental study of the process and obtain expert guidance in projecting the results to commercial operation, before he makes any commitment to manufacture the product for military purchase.

Fig. 1 Usual Harvesting Periods for APPLES by State and Variety



Source: U.S. Bureau of Agricultural Economics.
Apples: Usual Time of Bloom and Harvest...
Washington, D.C., 1950.

Figure 2

Flow-Sheet of Processes for Producing Dehydrated Apples

FOR APPLES, DEHYDRATED, TYPE I (SAUCE)

210 - Raw Material Handling
(Packaged Dried Apple Rings)

↓

Unpacking

↓

Breaking Up

220-230 - Preparing

↓

Inspecting

↓

Cutting

240 - Drying

↓

Tray loading

↓

Vacuum drying 1/

↓

Tray unloading

250 - Inspecting

↓

Inspecting

260 - Packaging & Packing

↓

Filling, packing, & sealing

↓

Case forming, filling, sealing, & marking

270 - Warehousing & Shipping

↓

Palletizing
Warehousing
Shipping

FOR APPLES, DEHYDRATED, TYPE II (PIE)

210 - Raw Material Handling
(Pre-Cut Dried Apples in Bulk)

220-230 - Preparing

↓

Inspecting

240 - Drying

↓

Air drying 1/

250 - Inspecting

↓

Inspecting

260 - Packaging & Packing

↓

Filling, packing & sealing

↓

Case forming, filling, sealing, & marking

270 - Warehousing & Shipping

↓

Palletizing
Warehousing
Shipping

1/ The distinction between Type I and Type II Dehydrated Apples is based on the size of individual pieces and the varieties of apples used, rather than on the method of dehydration (see pages 4, 5, and 6). Either vacuum drying or air drying may be used to produce both products.

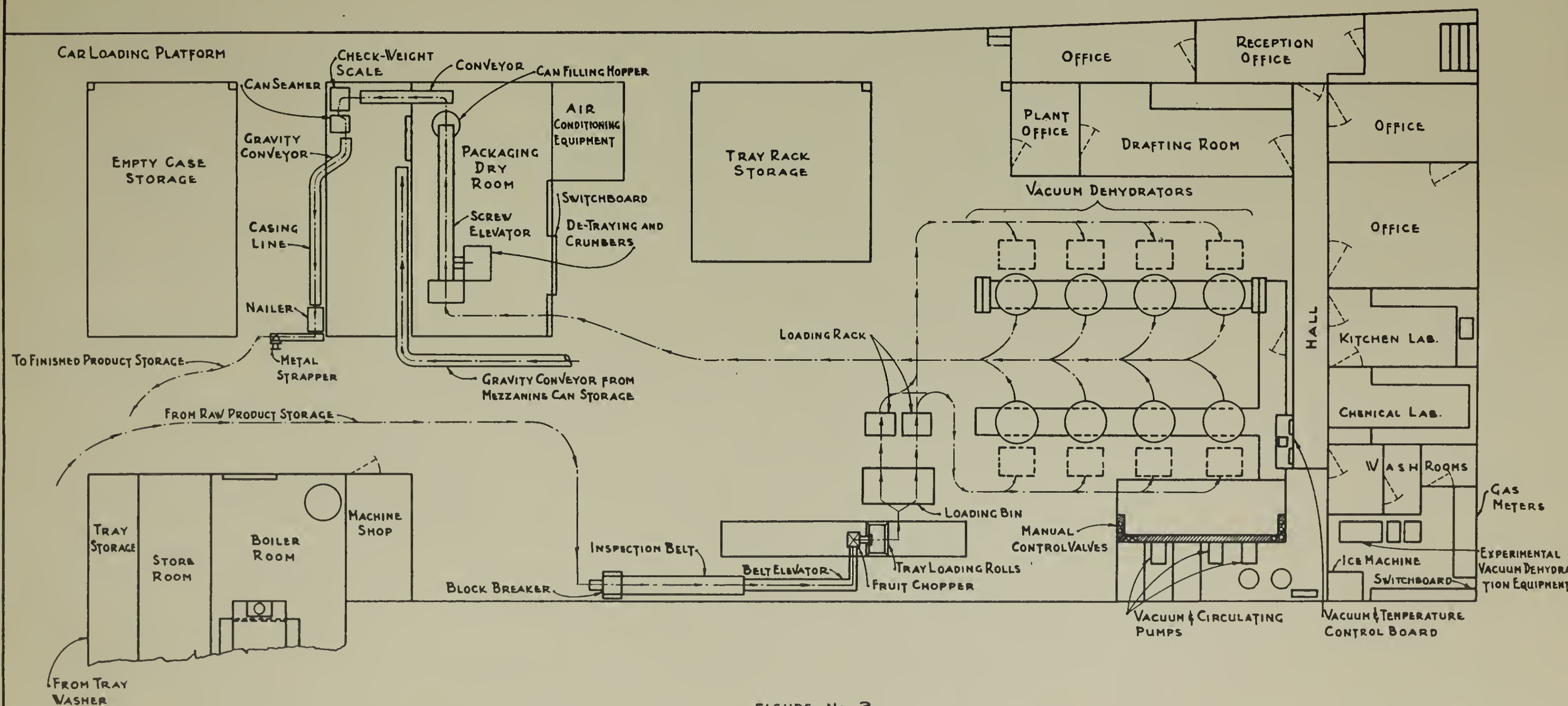


FIGURE No. 3

SCHEMATIC LAYOUT OF PLANT PRODUCING TYPE I APPLES, DEHYDRATED, BY VACUUM DRYING

(Courtesy "Food Engineering")

(Note: Certain Equipment Items which do not Pertain to Apple Dehydration have been Omitted from this Reproduction)

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